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MANUFACTURE OF CYLINDERS AND COOLING JACKETS OF INTERNAL COMBUSTION ENGINES

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In internal combustion and explosion engines, one of the recent preoccupations of technicians has been to improve the resistance to wear. Cast iron possessing a good coefficient of friction owing to the formation of graphitised surfaces is generally employed, but in certain cases it is unsuitable, either on account of insufficient mechanical resistance or for questions of lightness and cooling. Such is the case in particular with the cylinders of air-cooled aircraft engines.

Whereas annealed cylinders of medium-hard steel having about 0.60% of carbon have been used for this purpose, recourse has recently been had to cylinders of nitrided steels. The latter suffer from the disadvantage of necessitating the use of an aluminium steel which is delicate to work for the following reasons: ropy casting, inclusion of alumina, reduction in the hardening capacity, risk of increasing the size of grain in the alpha state, risk of fragility, and the like. Nitriding itself is a long and expensive operation. The restrictions of cementation by tinning, the impossibility of rectifying after nitriding owing to the slight thickness of the hardened layer, considerably complicate this manufacture.

The present invention relates to the use of a steel and a treatment whereby it is possible to produce homogeneous cylinders of very considerable hardness and having an excellent coefficient of friction under particularly easy conditions of manufacture, since hardening is effected after machining and without deformation.

The cylinders are forged from an extra hard manganese steel of the type commonly employed in the art of measuring instruments for the manufacture of plug gauges and calipers. This steel has the following approximate composition:

	Per cent
C	1.05
Mn	1.9
V	0.1

The forged piece may be suitably annealed in accordance with the classic technique:

a. After forging, homogenisation annealing at 920° C. for half an hour to the core, then homogeneity hardening by air cooling.

b. Then coalescent annealing for softening and grain regeneration at 790° C. for half an hour followed by slow cooling at about 4° C. per minute down to 550° C. and then as desired.

The Mesnager resilience (notched bar impact test value) after forging which was 1.25 metre-kilograms falls to 0.75 after homogenisation treatment in consequence of the superheating and the fineness of the structure of the lamellar pearlite, but the pro-eutectoid carbide grains are very fine and very regularly distributed. After the regeneration treatment and cooling at 4° C. per minute, the resilience increases to 5.5 for a rupturing load reduced to 80 kilograms. The structure is then extremely fine and regular.

The piece having undergone this double annealing is then machined completely with the exception of the bore, where a slight excess thickness is left to permit rectification and final polishing after hardening.

The completely machined cylinder is copper plated internally to protect it from decarburisation during the hardening heat treatment which takes place according to the following cycle:

After preheating at 700° C. stabilisation, heating is gradually raised to about 780° C. in the muffle furnace, the cylinder being placed vertically to avoid any viscous deformation. (Magnetic detection may be employed for ascertaining the end of heating.) The cylinder is then taken by means of suitable tongs to prevent deformation and rapidly plunged in a bath of molten salt at about 350° C., formed for example of the eutectic: sodium nitrate-potassium nitrate. The cylinder remains about 5 minutes in this bath and is then withdrawn and cooled slowly in still air. The cylinder is then tempered at about 250° C. for an hour and is then hardened. It then has a Rockwell cone hardness of 58 to 64.

In this state, the resilience of the metal is from 1 to 2 metre-kilograms, an excellent figure when it is remembered that, without the double annealing, it would have been 0.45 to 0.6 metre-kilogram, and that by oil hardening, a resilience incapable of measurement and comprised between 0 and about 0.3 metre-kilogram would have been obtained.

The cylinder is then cleaned externally and cadmium plated for protecting it from corrosion. It is then rectified internally and polished for obtaining a perfectly glazed cylindrical surface. The cylinder is then ready for mounting on the engine.

By this process, it is also possible to manufacture internal combustion engine jackets, more particularly water-cooled jackets. These are characterised by the absence of deformation permitting strict dimensions to be obtained, by the very slight thickness which permits excellent cooling, by their high mechanical properties and by an exceptionally good resistance to wear. By this process, it is possible to manufacture air-

cooled explosion engine cylinders having fins. Even though machining comprises recessing the fins for the passage of the columns connecting the cylinder heads to the crank case, the thermal treatment may be effected without appreciable deformation, the latter being much less than the variation in dimensions by the subsequent rectification.

The principle of this manufacture comprises employing a steel having a low transformation point to permit a variation in temperature of scarcely 400° C. during the hardening operation. It likewise comprises employing a steel having a sufficiently low critical hardening rate to be able to remain entirely in the austenitic state by quenching in a salt bath at 350° C. when in the condition of a thin piece of a few millimetres in thickness. Furthermore, no transformation takes place during the stay in the quenching or hardening bath. The transformation from austenite to martensite takes place in the subsequent air cooling. The temperature gradient is then very slight, the transformation takes place simultaneously and slowly at all points of the mass, reducing the internal stresses and deformation to a minimum. The risks of hardening fissures are non-existent.

The steel is selected to have a high mineralogical hardness and consequently a good resistance to wear. It is likewise selected to have a very good coefficient of friction and more particularly a good capacity for the formation of unctuous films with the lubricating oils.

The carbon and manganese permit all the desiderata expressed to be met completely. They satisfy these better than any other addition element.

The steel may in addition contain very small contents of elements such as vanadium, adapted to result in a fine austenitic structure by considerably raising the temperature of the increase in size of the grain. It may contain a small addition of molybdenum with a view to improving its behaviour when hot and reducing the viscous deformation.

Advantageously, it will contain a very low silicon content, little vanadium and little molybdenum for maintaining a fairly low transformation point. The most suitable compositions are comprised between the following limits:

C	0.85 to 1.25
Mn	1.5 to 2.40
V	0.150
P	Minimum
S	Minimum
Si	Minimum

In addition, it may possibly contain molybdenum with a content below 0.50%; titanium or aluminium in partial or total replacement of the vanadium; nickel or chromium in partial replacement of the manganese; chromium or tungsten in partial or total replacement of the molybdenum. In these replacements, the manganese may be considered as equivalent to a double content of nickel or chromium; the molybdenum as equivalent to a triple content of tungsten or chromium. These modifications, however, do not seem to bring about any marked improvement.

The hardening temperature may vary from 740 to 820° C. according to the composition. The most advantageous temperature is that of the end of the alpha-gamma transformation on heating, below this the hardening is incomplete, above, the solution of the pro-eutectoid carbon is undesirable, harmful to the friction properties and results in fragility of the steel. Furthermore, the hardening deformation may become appreciable if the heating temperature before hardening is too high. It is necessary during the heat treatment to avoid decarburisation of the surface of the cylinder both on account of the slight thickness removed by rectification and in consequence of the necessity, for avoiding hardening deformation, of effecting a martensitic transformation at all points of the piece simultaneously. Electrolytic copper-plating is particularly recommended on account of the ease of carrying it out and the good exchange of heat of the surface during hardening, but it is also possible to effect protection from decarburisation by coating with an aluminium paint (aluminium powder with gum lac or the substance known by the registered trade-mark Bakelite) or by heating in an inert reducing or carburising atmosphere; or by heating in a salt or lead bath.

The hardening bath may be of any desired kind, for example: cyanide-cyanate, metal bath, or the like. Good results are obtained by employing the sodium nitrate-potassium nitrate eutectic, which is quite commonly used.

The temperature of the hardening bath and the length of stay of the piece in the hardening bath varies with the composition of the steel, the mass or thickness of the parts to be hardened, the composition of the hardening bath, between the limits 300°–400° C.

It is also necessary to allow for the heating of the bath by the introduction of the heated piece.

The best results are obtained when the temperature is such that no transformation takes place in the hardening and in the subsequent stay in the hardening bath. This is easily ascertained by the absence of ferro-magnetism. The piece is not attracted by a magnet on leaving the hardening bath.

The temperature and the subsequent time of tempering may be modified according to requirements, the preceding values being given only by way of example. Thus, the tempering temperature may be so much lower, the better the cooling in service, the smaller the cylinder or the lower the power.

I claim:

1. A process for manufacturing cylinders and cooling jackets comprising forging an extra hard carbon steel having 0.85 to 1.25% carbon, submitting the forged metal to an annealing treatment, machining the pieces, heating the machined pieces to a temperature above 700° C., hardening the pieces in a molten salt bath at a temperature between 300° and 400° C., and finally cooling the pieces slowly in still air.

2. A process as claimed in claim 1, in which the pieces are at the end of the heating treatments rectified internally and if necessary polished.

3. A process as claimed in claim 1, in which the pieces are internally covered with copper after machining and before the hardening heat treatment.

4. A process for manufacturing cylinders and cooling jackets comprising forging an extra hard carbon steel having 0.85 to 1.25% carbon, and at least one metal selected from the group consisting of 1.5 to 2.4% manganese, an effective amount to 4.8% chromium and nickel, an effective amount to 0.15% vanadium, an effective amount to 0.15% titanium, an effective amount to 0.15% aluminium, an effective amount to 0.5% molybdenum and an effective amount to 1.5%

tungsten, submitting the forged metal to an annealing treatment, machining the pieces, heating the machined pieces to a temperature above 700° C., hardening the pieces in a molten salt bath at a temperature between 300° and 400° C., and finally cooling the pieces slowly in still air.

5. A process of manufacturing cylinders and cooling jackets comprising forging a steel having 0.85 to 1.25% carbon and 1.5 to 2.4% manganese, annealing the forged metal, machining the forging, heating the forging to at least 700° C., quenching the heated forging in a molten salt bath at 300 to 400° C., and finally cooling the forging slowly in still air.

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